American Public Transportation Association Annual Meeting

Alternative Fuels Committee

September 22, 2002, Las Vegas

Diesel Emission Reductions: A Study of Transit Bus Alternatives for California

California Environmental Protection Agency

Air Resources Board

ARB's Bus Emissions Project Goals

- Compare "clean" CNG and "green" diesel transit bus emissions

- Determine emissions for several toxic substances of risk significance

Scope and Methods

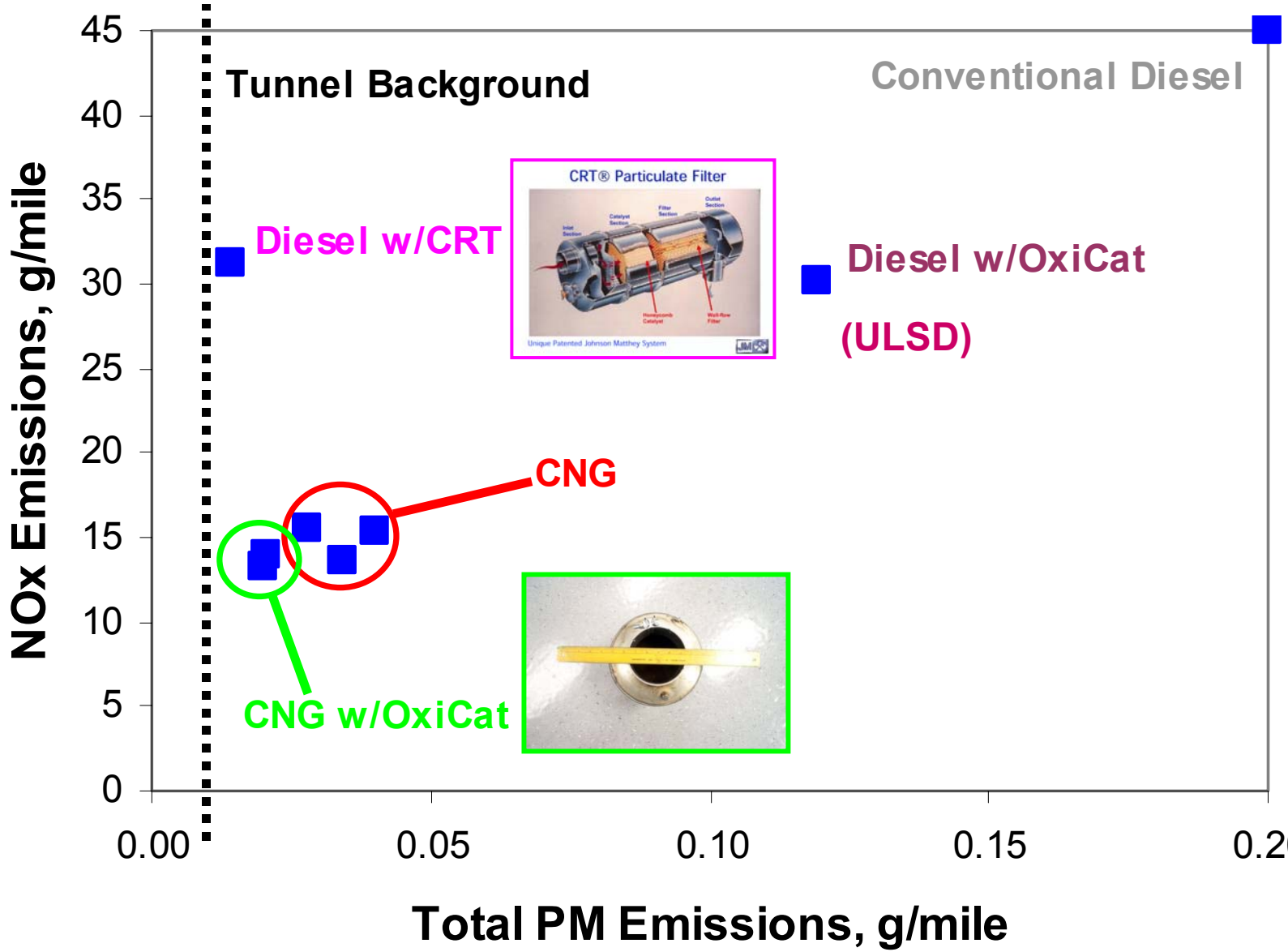
- Cycles: Idle, 55mph Cruise, CBD, NYBC, UDDS
- PM: filters and MOUDI
- Total HC's: heated FID
- NO_X, NO_2: chemiluminescence
- CO, CO_2: NDIR
- Carbonyls: DNPH cartridges/HPLC
- Metals: teflon filter/XRF
- Mutagenicity: filter/PUF/XAD, modified Ames assay
- PAH's: filter/PUF/XAD, GC-MS
- EC/OC: quartz filter/TOR
- VOC's and NMHC: tedlar bag/GC
- PM number/size: SMPS & ELPI@micro-diluter and SMPS@CVS

California Environmental Protection Agency
Air Resources Board

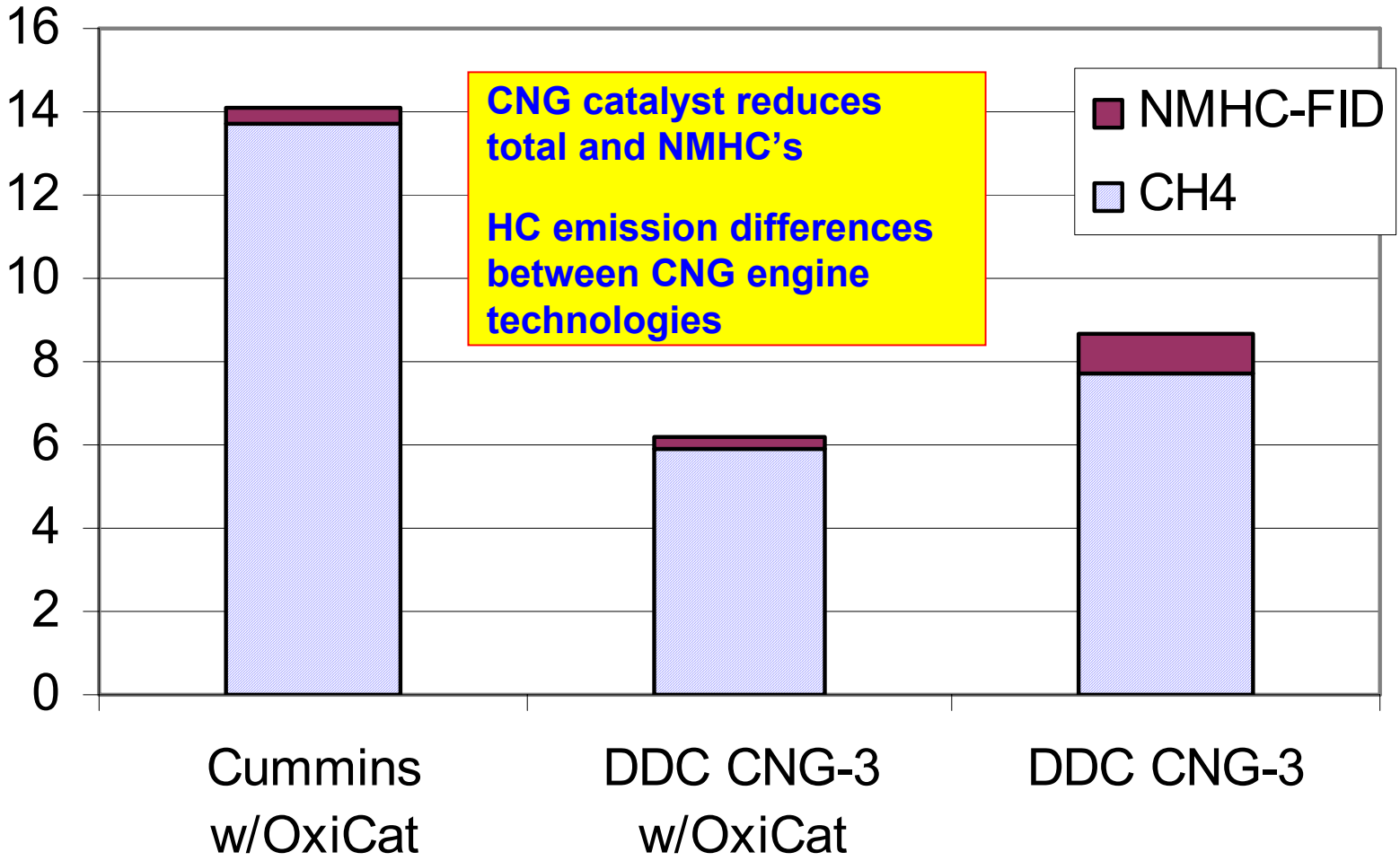
Test Vehicles

	DDC	Cummins	DDC
Data label	Diesel Baseline and Diesel CRT	Cummins w/Oxi Cat	DDC CNG-3
Vehicle	#3007	#134	#5300
Fleet	Los Angeles MTA	Omnitrans	Los Angeles MTA
Chassis	New Flyer	New Flyer	New Flyer
Capacity	40 passenger	40 passenger	40 passenger
Fuel	ECD-1	CNG	CNG
Engine	Series 50	Cummins Westport C Gas Plus	Series 50 G
Model year	1998	2001	2000
Mileage at start:	15,169	18,700	19,629 and 56,600
Aftertreatment	OC and DPF	Oxidation Catalyst (OC)	OEM* and OC**

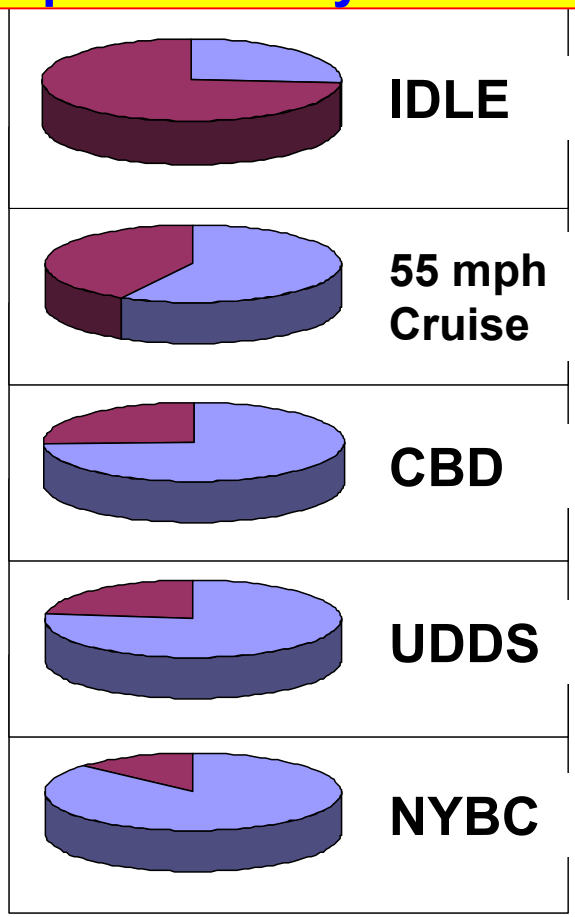
**OEM configuration is with no controls* ***1st DDCS50G w/Oxi Cat on New Flyer chassis*

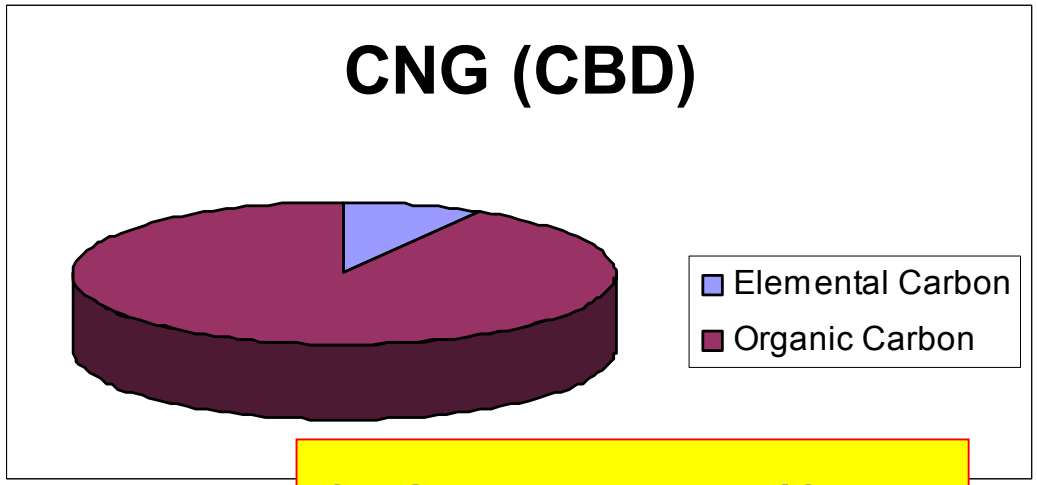

NOx Emissions, g/mile
45
40
35
30
25
20
15
10
5
0
0.00
0.05
0.10
0.15
0.20
Total PM Emissions, g/mile
Tunnel Background
Conventional Diesel
Diesel w/CRT
CRT® Particulate Filter
Diesel w/OxiCat
(ULSD)
CNG
CNG w/OxiCat

Total HC g/mi Emissions from CNG Buses (CBD)

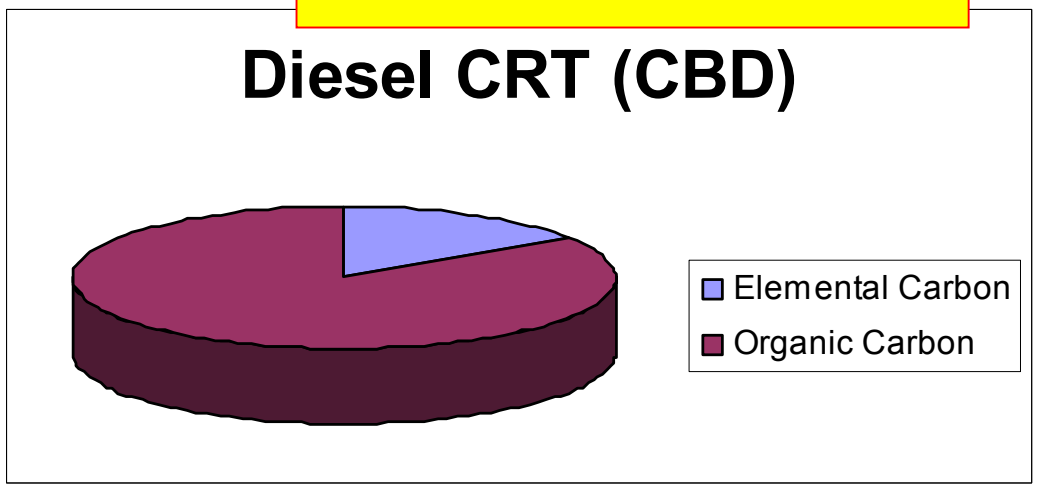


Diesel PM Composition Depends on Cycle

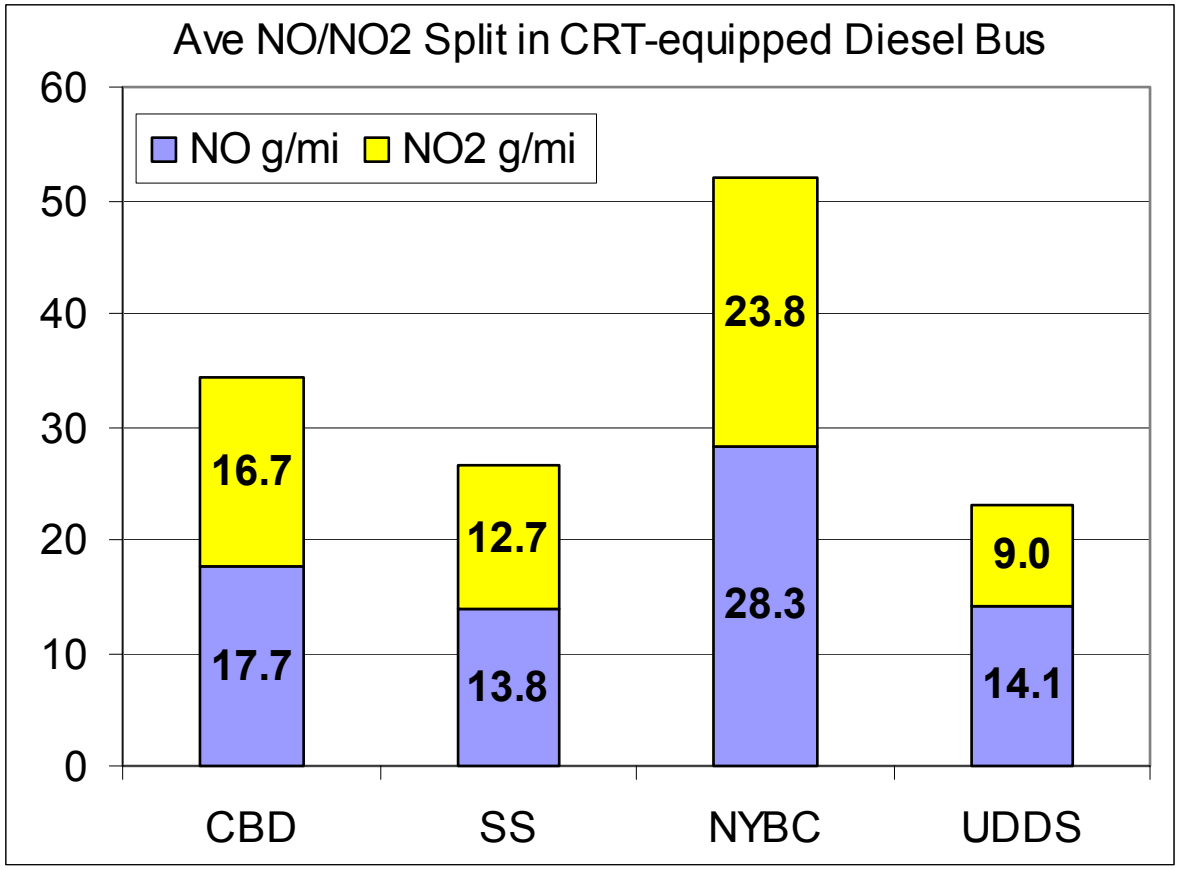




CNG and Diesel w/CRT PM composition is primarily OC for all cycles



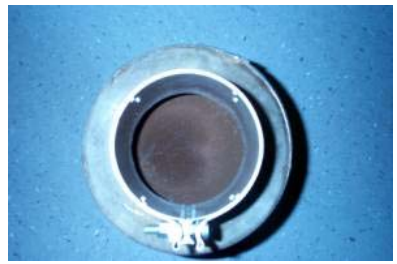
CRT Effect on Diesel Bus NO_X Emissions



Diesel baseline NO_2/NO_X ratio ~10% or less

ARB's ambient modeling suggest that a modest increase in the NO2/NOX fraction (20-25%) results in more benefits than disbenefits

"Species of Toxic Risk Significance to Natural Gas Buses" (SCAQMD 1192 Rule Report)



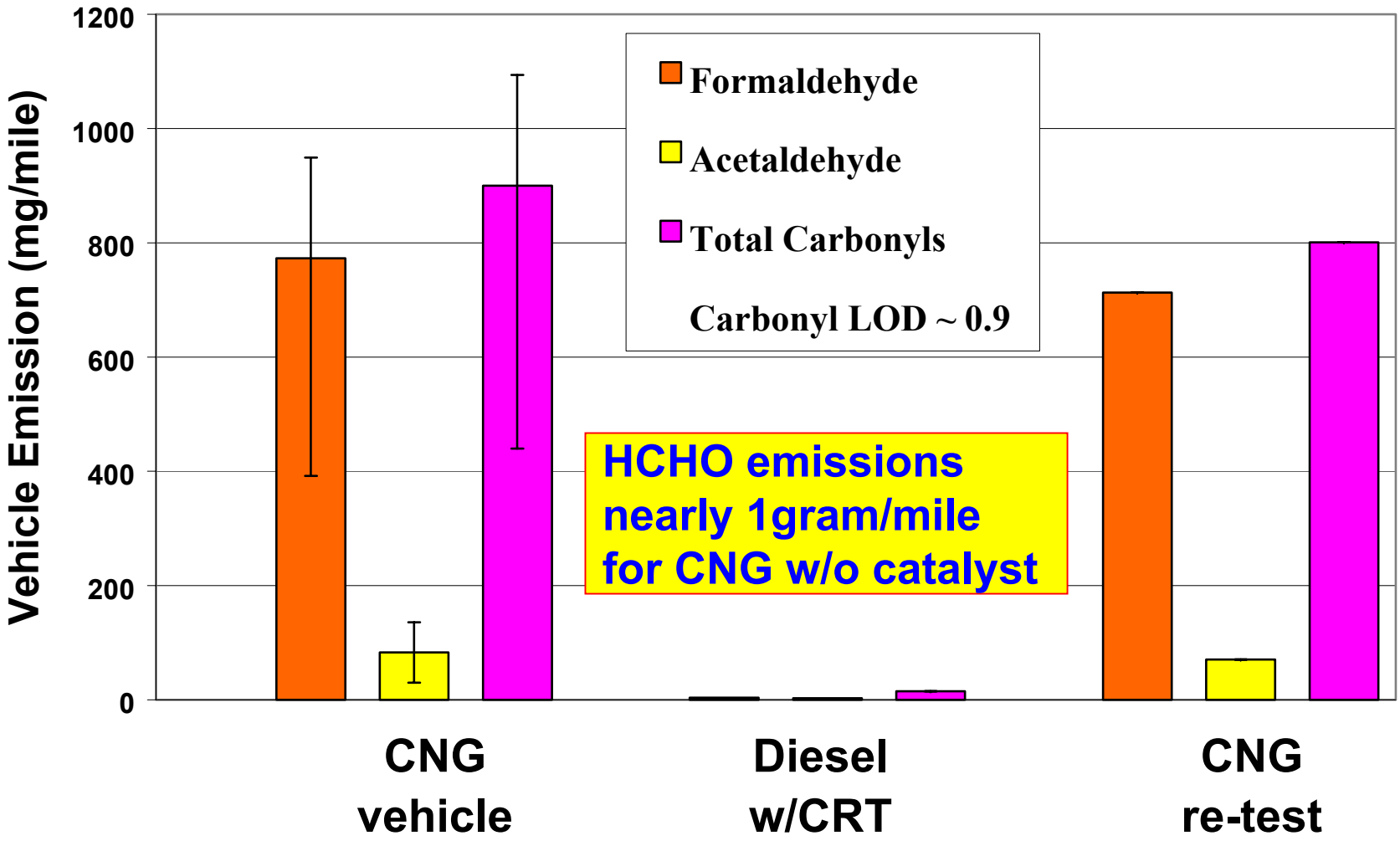
	NO Oxi Cat	WITH Oxi Cat
GAS PHASE	(miligram/mile)	
Formaldehyde	~ 900	90+ % reduction
Acetaldehyde	~ 80	Reduced
Benzene	~ 3	Possible reduction
1,3-Butadiene	~ 3	Below detection
PM PHASE		
Nickel*	~ 0.002	***pending***
Chromium*	~ 0.003	***pending***

* Preliminary data

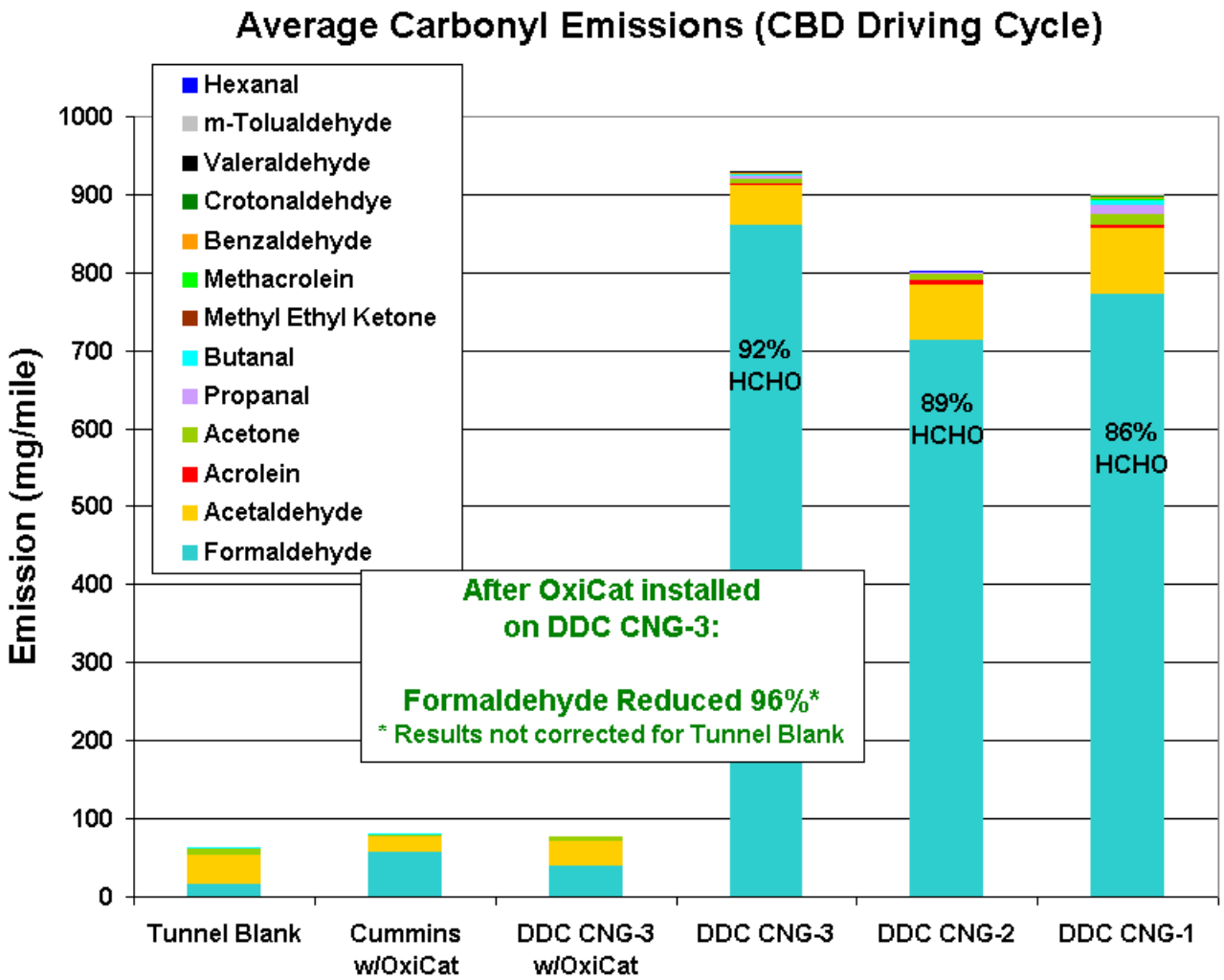
All emission factors over CBD

Carbonyl Emission for CBD Cycle

(range of values for multiple tests denoted)

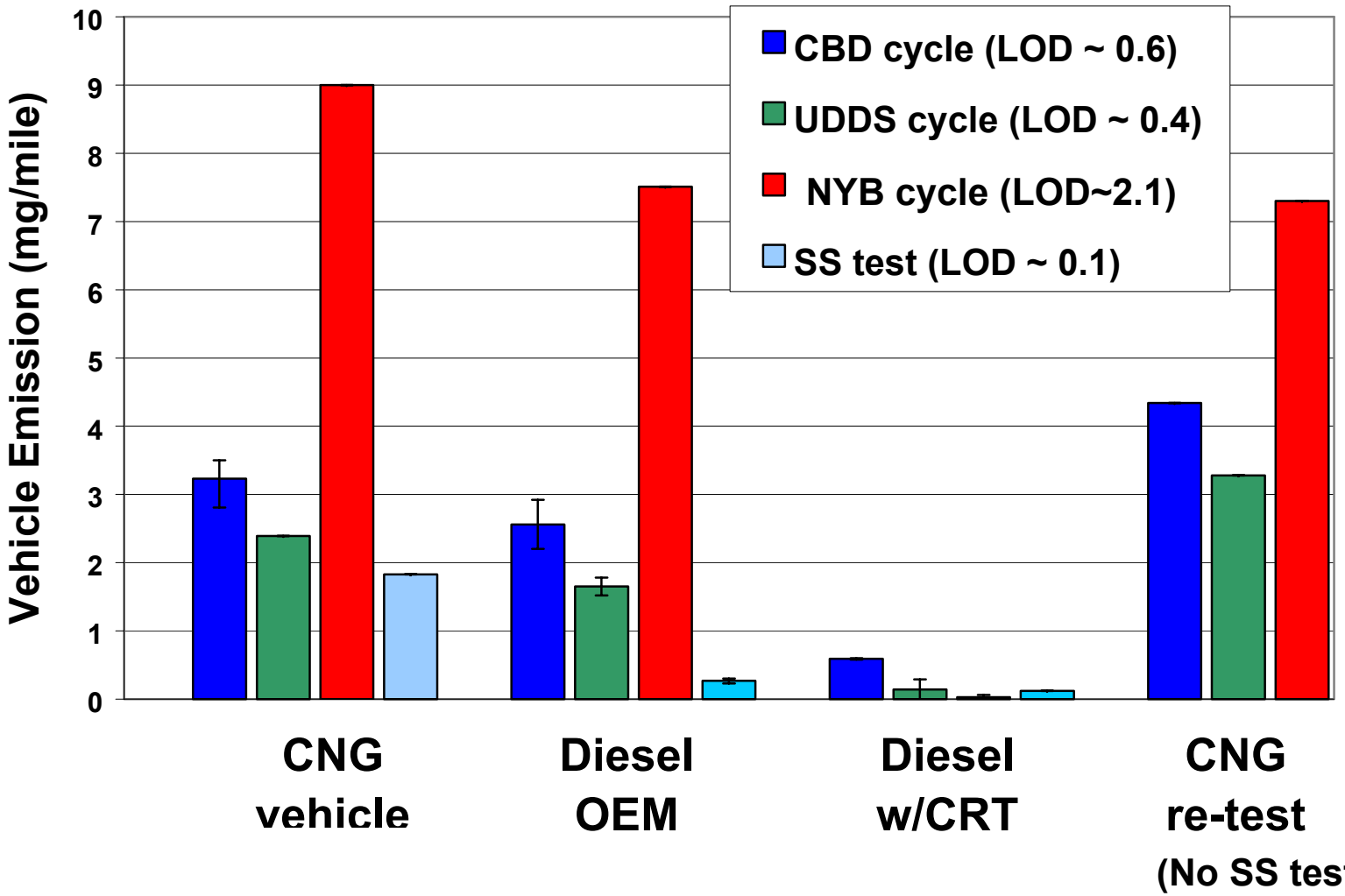


CNG Oxidation Catalyst Effect

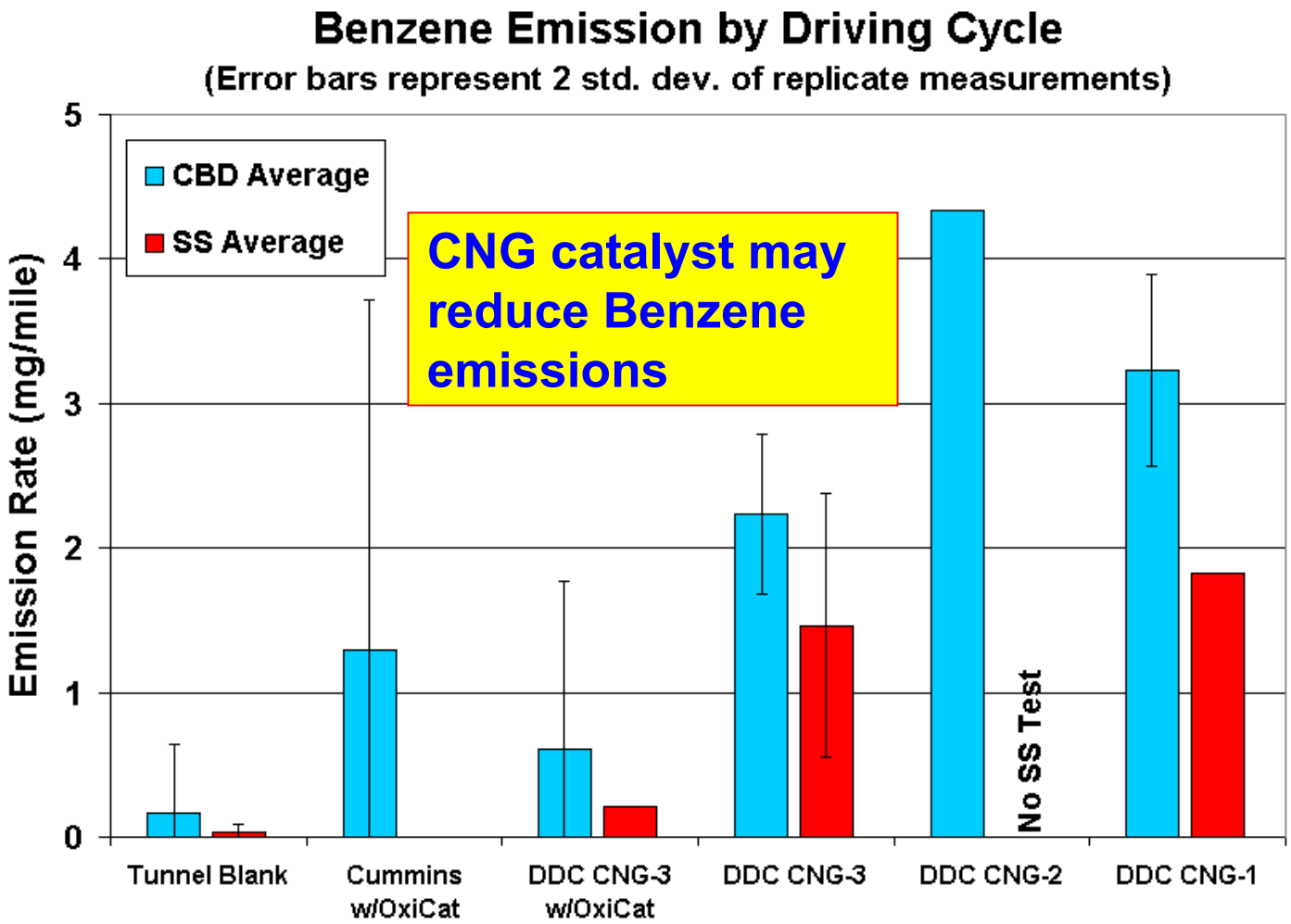


Benzene Vehicle Emission

(range of values for multiple tests denoted)

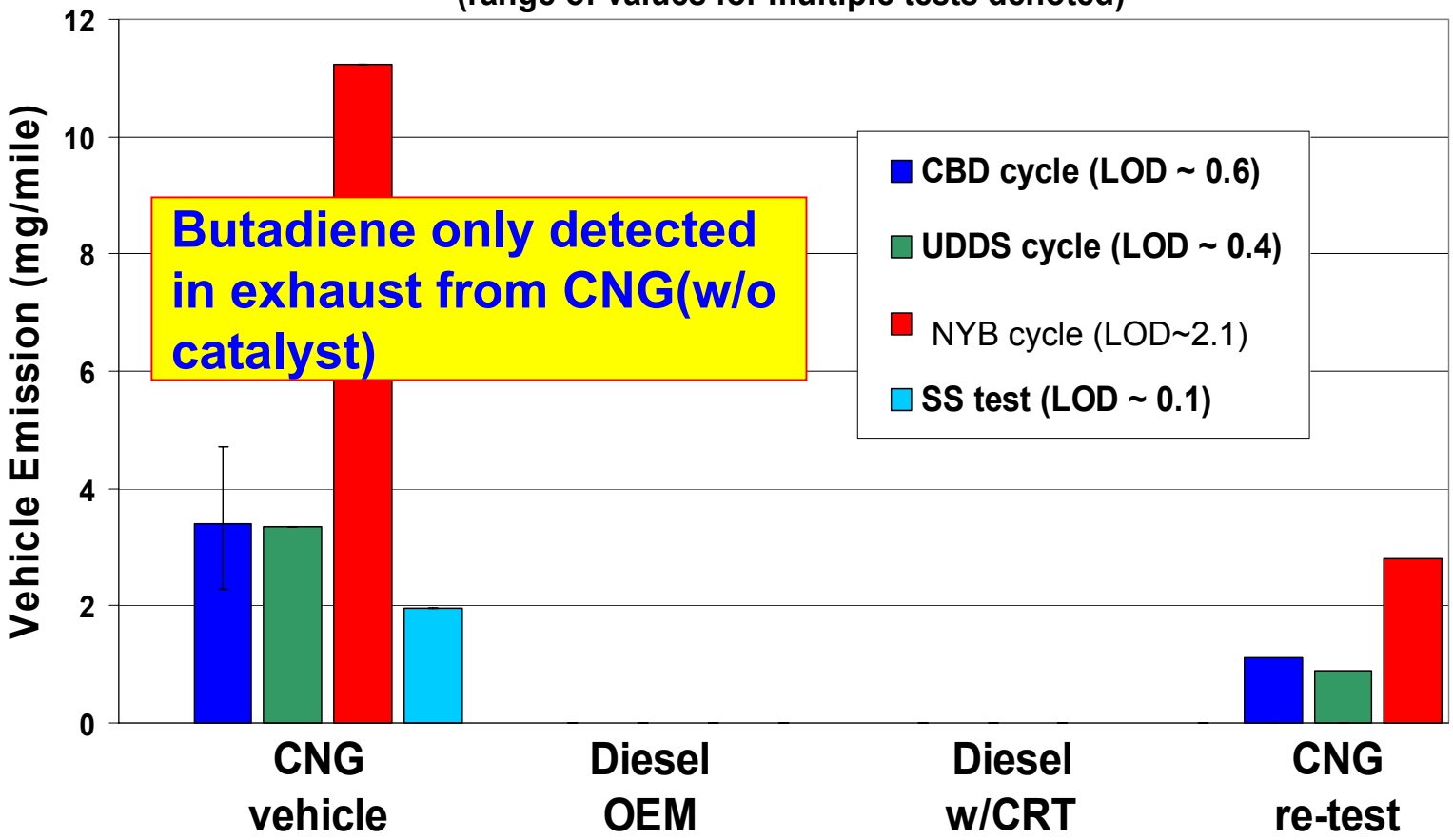


CNG Oxidation Catalyst Effect



1,3 Butadiene Vehicle Emission

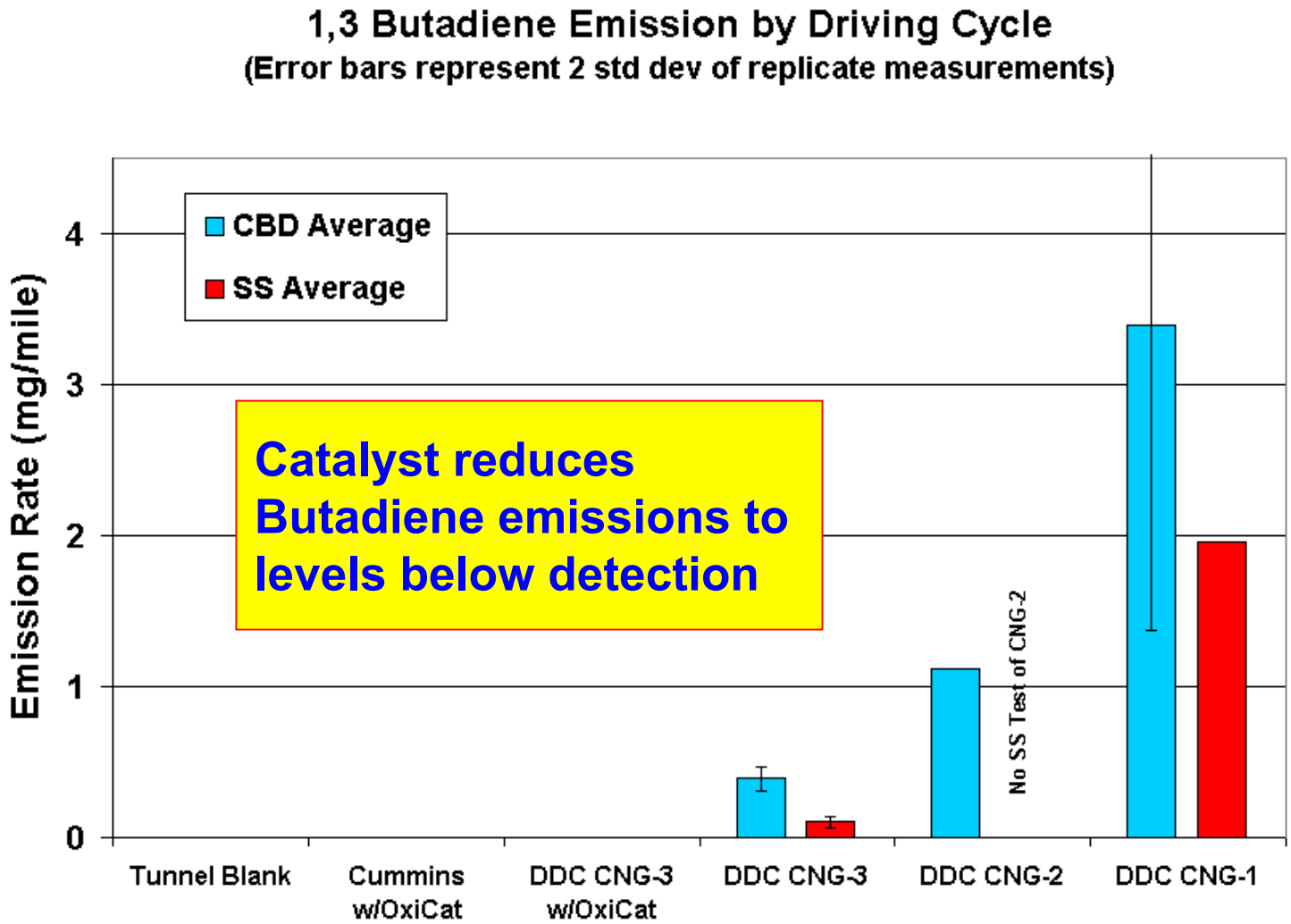
(range of values for multiple tests denoted)



Note: 1) Measurements showed high variability.

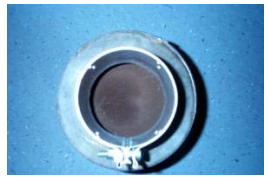
2) Tunnel background measurements were below detection limits.

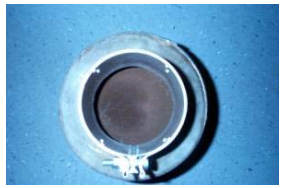
CNG Oxidation Catalyst Effect



Other Toxins of Significance to Transit Buses

Aftertreatment

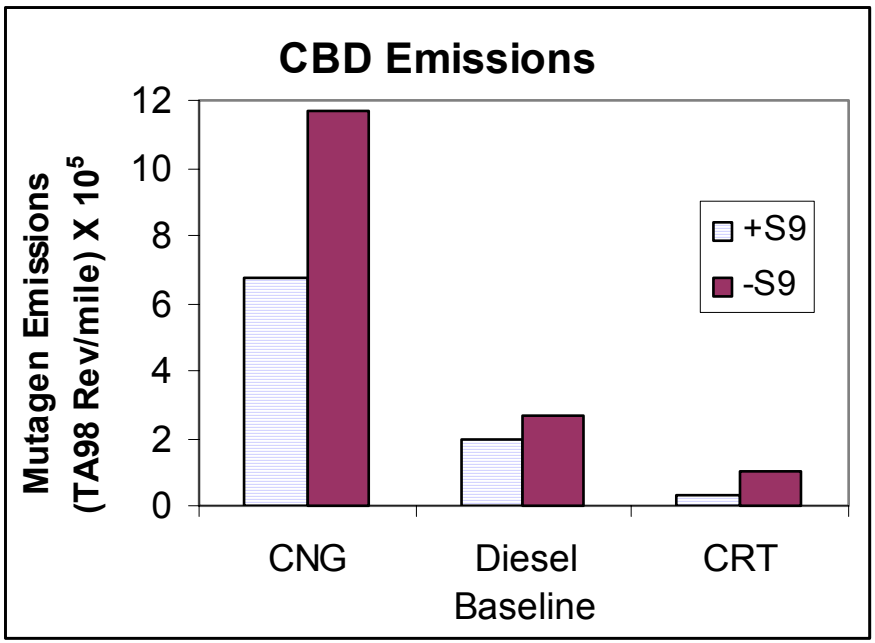


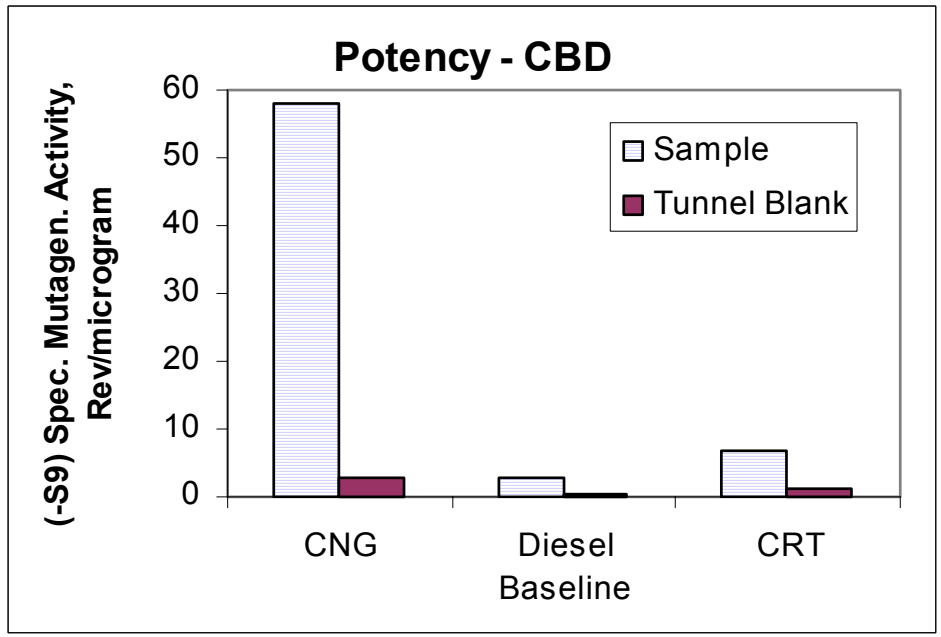


	Diesel (OC+ULSD)	Diesel w/CRT	CNG	CNG w/Oxi Cat
GAS PHASE				
PAH's	✔	✔	✔	*pending*
Ames Assay	✔	✔	✔	*pending*
Other VOC's	✔	✔	✔	✔
Other Carbonlys	✔	✔	✔	✔
PM PHASE				
PAH's	✔	✔	✔	*pending*
Ames Assay	✔	✔	✔	*pending*
Inorganic Species	✔	✔	✔	*pending*
Other Particle Number	✔	✔	✔	✔

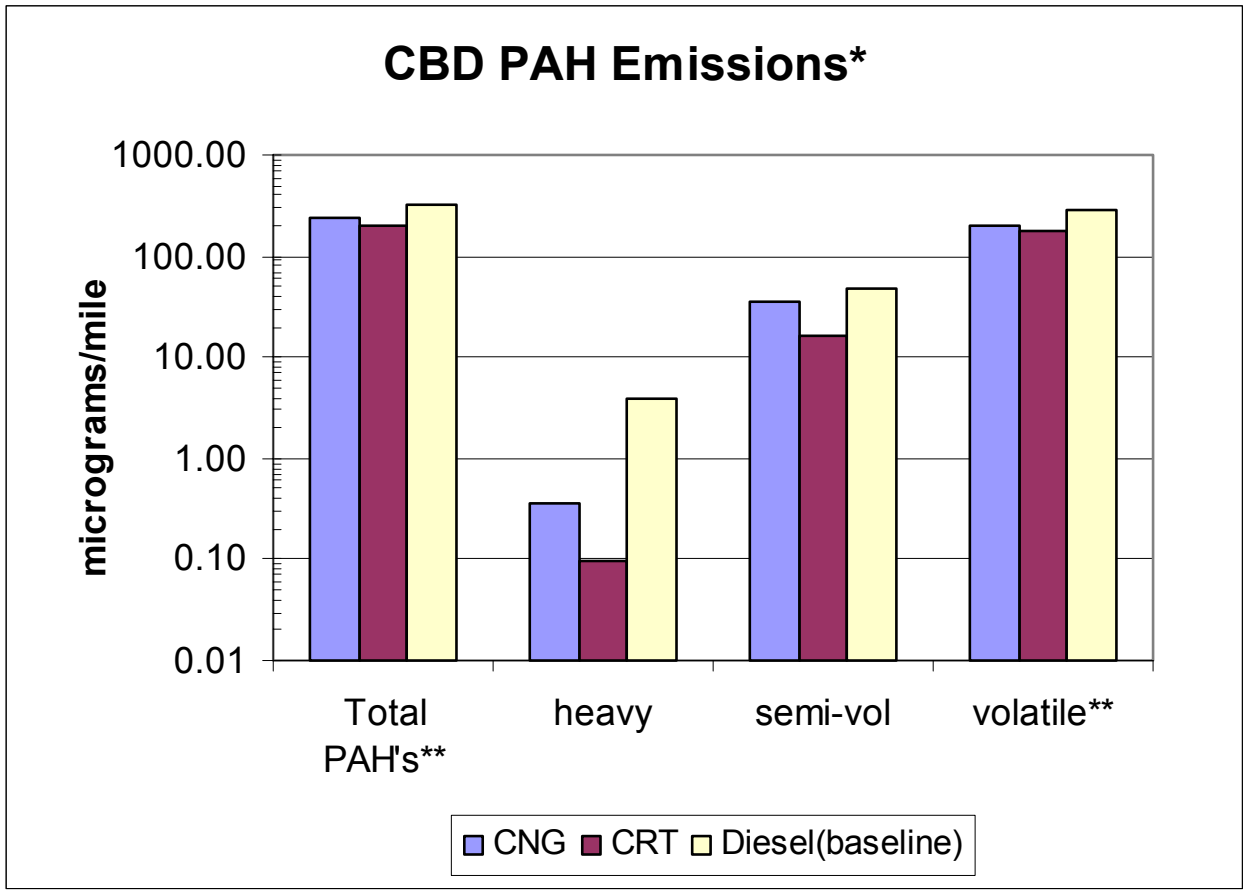
Modified Ames Assay Results

TA98 and TA100 w/ and w/o S9





Polycyclic Aromatic Hydrocarbons

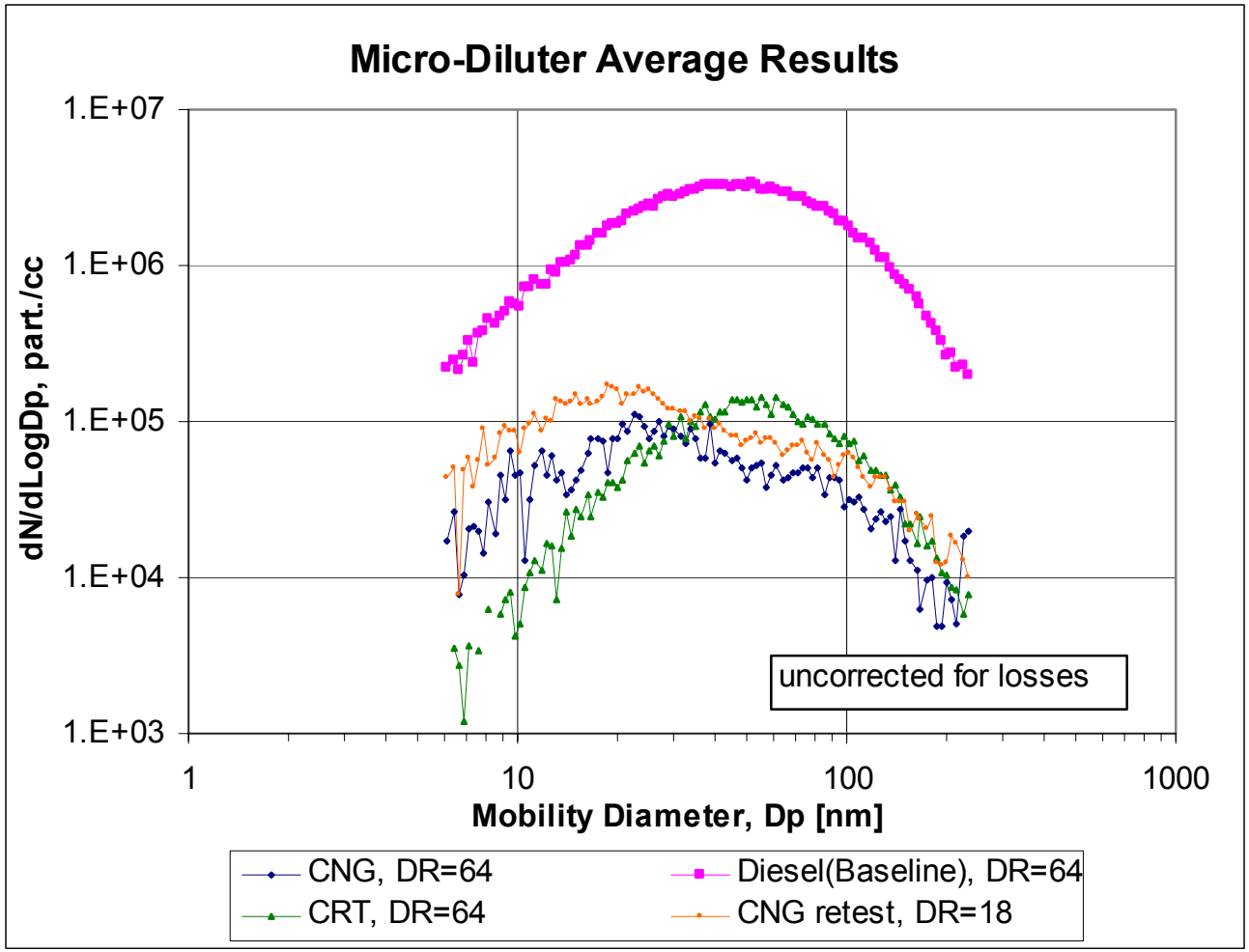


* All results uncorrected for background

** Excluding Naphthalene

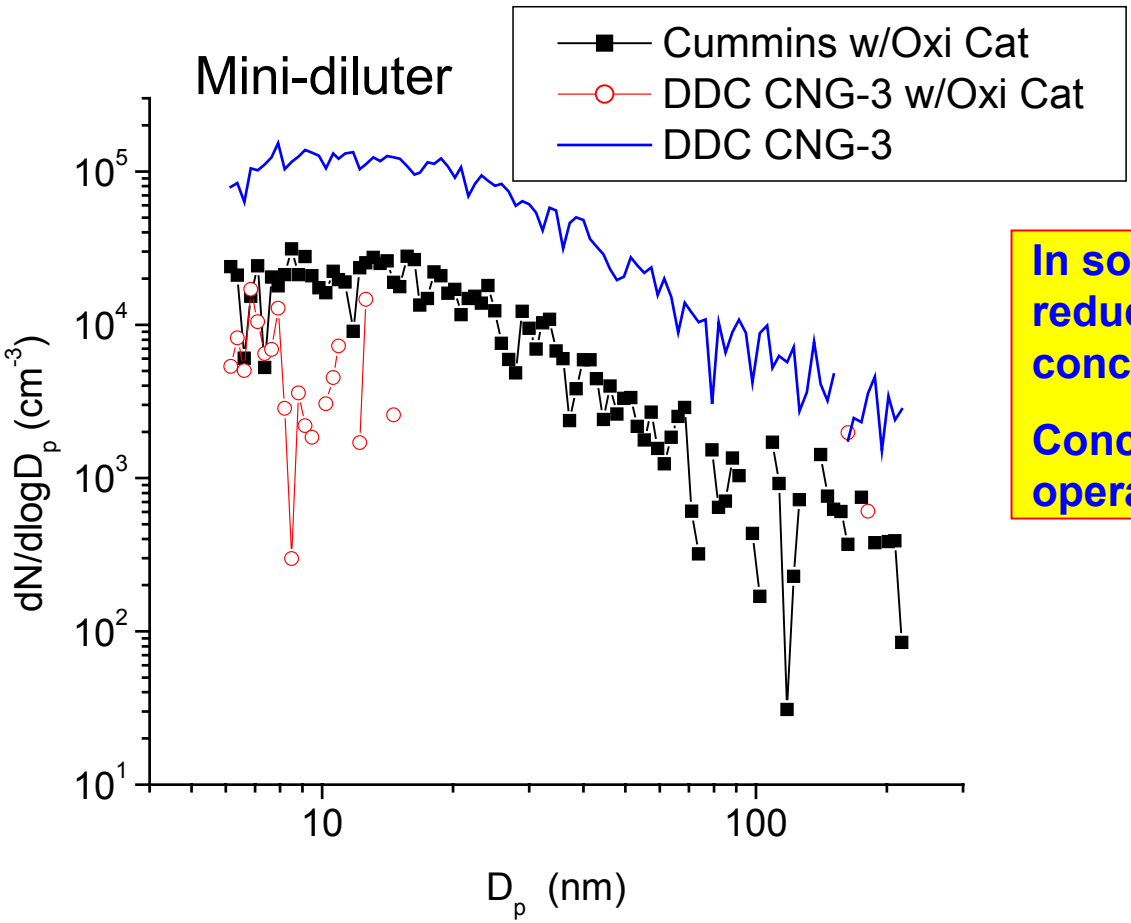
Particle Size Distributions

Steady State (55 mph) Cruise



CNG Catalyst Effect

Particle Size Distribution (55 mph Cruise)



In some cases, OxiCat in CNG reduces particle number concentrations

Concentrations depend engine operating condition

Final Remarks

- Reduction of diesel emissions from heavy-duty vehicles is a priority
- Transit buses impact urban areas
- Current CNG-fueled and DPF-equipped diesel transit buses are superior to conventional diesel buses
- No “clean” technology is clearly superior to other. Both can be improved.
- CNG bus without aftertreatment has measurable levels of toxic and nanoparticle emissions and Ames assay activity relative to similar diesel buses with aftertreatment (and ULSD)
- Based on partial results, catalyst for CNG applications offers significant benefits